Post-Harvest Stored Product Insects and Their Management

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Food security is one of the major concerns in many countries. Preservation and storage of food grains, mainly for future consumption for the non-producers is greatly important and inevitable. Stored products/commodities are prone to many biotic and abiotic factors. Among biotic factors, insects are considered as the major threat causing nearly 10% of total storage. Though, there are several species of insects that infest and spoil stored commodities, but nearly hundreds of such species are causing severe losses. In this publication 15 such important and very common and prevalent stored product grain insect are explained in brief with their life cycle, effects on grain and their management. Although the majority of the photographs used are original to the authors, some are also taken from the open sources. We appreciate and acknowledge the sources. This publication might help the non-entomologists working in post-harvest storage aspects to know the basic biology, lifecycle and infestation mechanism of the stored product insects.
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1. Introduction

Advancement of technologies in agriculture has led to increased food production every year. In many countries, major portion of the food grains produced, were storing for contingency and regular supply. These stored grains were infested by insects directly or indirectly and causing severe damages, apart from other storage losses. Most of the storage part is mainly concentrating on grain storage either in domestic or commercial scale. Several structures were used for grains storage ranging from a small metal bin to tall grain elevators. Such stored commodities for long time were prone to contamination and damage by biotic and abiotic factors. Among the biotic agents, insects, mites, rodents, birds and microorganisms cause immense loss in storage. Major damage was mainly caused by insects, which account for an average of 10-20 per cent of storage losses (Phillips and Throne 2010). In general, stored products of agricultural and animal origin are attacked by more than 600 species of coleopterans, 70 species of lepidopterans and about 355 species of mites. They are causing both quantitative and qualitative losses (Rajendran and Sriranjini 2008).

The insects damaging the stored grains, many times got access from the field and established at the storage site due to microclimate and retained during the course of processing and storage (Hagstrum and Phillips 2017). Reports have shown that some insect pests initiate damage during ripening stage of crops and continue to storage. However, major sources of infestations are old bags, storage structure, old containers and cross over infestation (Perez-Mendoza et al. 2004), harvesters and other machineries (Sinclair and White 1980). The initial infestation can be minimized during the post-harvest handling to the storage structures by proper harvesting and drying of grains. However, between the lots the movement of stored product insects are facilitated by grains supply from one region to another either through the commodity. Sometimes they also spread by active flight of insect pests as many of them are strong fliers (Mahroof et al. 2010; Ridley et al. 2011a, b). Nearly 100 species of insect pests of stored products lead to economic losses. It is estimated that in India, crop loss due to pests ranges from 10-30 per cent a year, out of which 26 % is due to the insect pests.

Storing of food grains throughout the World is an age-old practice. The period of storage from harvesting to the consumption of grains is either seasonal for seed purpose or over the years for buffer stock. During storage, the grains undergo several changes due to physico-chemical and biological grain metabolism which led to their deterioration. The physico-chemical changes may
occur due to abiotic factors like temperature, carbon dioxide, oxygen and moisture level, while biotic factors included fungi, bacteria, insects, mites, rodents and birds.

Stored-grain insect-pests may cause as much damage during storage as crop insect-pests cause during the growing season. Insects can damage the grains by direct feeding or indirectly by deterioration and contamination of grain by their faecal matter, exuviae or secondary infestation. Direct feeding damage results in reductions in grain weight, nutritional value, germination and market value. Whereas, deterioration and contamination from the presence of insects results in downgrading of grain and market value due to insect parts, odours, molds and heat damage.
The quantity so wasted is enough to feed at least 50 million people. This loss is not merely in terms of quantity but also in terms of quality of food grains. Many insect species are associated with stored grains and their products, but only about 50 are severe, either occasionally or frequently. The relative abundance of particular species may vary from country to country. Majority of them are distributed throughout the world and were reported to cause similar type of damage everywhere, although damage severity varies. In many cases, complexes of the insect species are present in the commodity lot as their feeding niche is different and can sustain simultaneously. The particular insect present also depend on the type of the stored grain and region of warehouse.
2. Classification

The commonest classification of the storage insects is based on their feeding habits as ‘primary pests’ and ‘secondary pests’. Primary feeders are those, which are able to damage the whole, undamaged grains. Their lifecycle involved with the whole grain as their young ones bore and feed inside the kernel part of the grain which sometimes creates ‘hidden’ infestation. These can cause very severe damage to the lot and if unnoticed till their population establishment, they are hard to manage. Regular monitoring is the essential step for preventing their damage. Secondary feeders are generally called as ‘bran bugs’ because they establish on the grains, which were already damaged either by the primary pests or other miscellaneous damages. They generally survive on broken kernels, debris or higher moisture weed seeds. The immature stages of these insects were found external to the grains and generally cannot initiate the infestation of the whole grains. But once after establishment these are generally contributing to spoilage, but not as severe as primary insects do. Their damage can be easily identified as their life stages were mobile in the commodity area. Some of the external pests are also mold/ fungal feeders. They contaminate the grains through their presence and metabolic

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wastes, which generates moisture (excretion and condensed heat) for mold development (Magan et al. 2003). Thus, the mold development indicates the final condition of grain spoilage. Common mold feeders include foreign grain beetle, rusty grain beetle, hairy fungus beetle, and psocids. The major insect pests causing damage in storage were listed in table I.
3. Grain weevils

a. Rice Weevil: *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae)

Rice weevils are prolific breeders and can build up huge populations in stored grains to the point where the grain has little value as a food product. During heavy infestations, heat and moisture are

**Egg**
- Translucent white, plugs the egg hole with gelatinous secretion, laid singly on grains.
- Female weevils will deposit 300-575 eggs in grains over a 6-8 month life span.
- Eggs hatch in about three days.

**Adult**
- These small beetles are reddish brown, and about 2.5 mm long and have 4 yellowish patches.
- They have distinctively long snouts and numerous round pits on the thorax.
- These weevils are able to fly.

**Larvae**
- The immature stage is approximately 2-3 mm long, white to yellowish in colour.
- It has a grub like appearance and has no visible legs.

**Pupae**
- The pupa is naked and the pupal stage lasts an average of 6 days.
- Pupates inside the grain.

*Figure: Rice Weevil: *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae)*
produced, leading to colonization by molds and mites. Attacks from *Sitophilus oryzae* can start in the field, when the moisture content is about 20%.

- **Distribution and status:** World-wide and is found practically throughout India. It is the most destructive pest of stored grain. The rice weevil may be found in the paddy fields as well.

- **Host range:** Wheat, oats, rye, barley, rice, and maize.

- **Damaging stage:** Both the adult and larva (grub)

**Symptoms of damage:**

The adults attack whole grains. Both adults and grubs feed inside grains, leaving large cavities and emergence holes. The adults also attack damaged grains.

**Detection:**

The eggs, larvae and pupae are not normally seen because they develop inside intact grains. The larvae chew large, irregular holes in the germ and endosperm of the kernel. Adult emergence holes (about 1.5 mm diameter) with irregular edges are apparent some weeks after the initial attack. Two rice weevils may develop at the same time on two sides of a single kernel. Adults can be found wandering over the surface of grain. In a heavy infestation, the only part of a grain that remains is the shell of the kernel perforated by adult feeding and emergence holes. Male *S. Orzyae* produce an aggregation pheromone ((4S, 5R)-5-Hydroxy-4-methylheptan-3-one) to which males and females are drawn.

b. **Granary weevil: *Sitophilus granarius* (L.)(Coleoptera : Curculionidae)**

Granary weevil is a small, moderately polished. The insect resembling the rice weevil, and is commonly confused. It prefers a temperate climate. Both the adults and larvae feed voraciously on a great variety of grains. Female make a scoop in grain and then deposits an egg and covers it with a gelatinous fluid. In warm weather, the granary weevil develops from the egg to the adult stagein
about 4 weeks. Cold weather greatly prolongs the developmental period. The life cycle is similar to rice weevil.

c. **Maize weevil: *Sitophilus zeamais* (Motschulsky) (Coleoptera : Curculionidae)**

It distributed in tropical and temperate areas, warm humid areas where corn is grown but can be found in colder climates like Canada also. The weevil having a major host range of maize, rice, sorghum, wheat, cassava and yam, and also dried stored products, including pasta. Both the grubs and adults are damaging stage. The life cycle is similar to rice weevil.
4. Grain borers

a. Lesser grain borer: *Rhyzopertha dominica* (Fabricius) (Coleoptera: Bostrichidae)

The lesser grain borers a commonest grain boring beetle in the country. It is small and was also commonly known as wheat borer. The insect can be easily distinguished by its reflexed head, which

**Egg**
- The female lays her eggs one at a time or in batches of up to 30 and can lay up to 500 eggs over 3 or more months.

**Adult**
- The adult beetle is dark reddish-brown with a cylindrical body about 3 mm long.
- The adult may live up to 240 days and is a strong flier.

**Larvae**
- The larva is white, and as it matures, it becomes C-shaped and immobile.
- White, apodous with brown head, free living up to 3rd instars.

**Pupae**
- Grub enters the grain after 3rd instar for pupation.

Figure: Lesser grain borer, *Rhyzopertha dominica* (Fabricius) (Coleoptera: Bostrichidae)
is a typical character of its family. This beetle is tropically originated and most commonly encountered in India in cereal grains stored under temperature range of 20-30 °C, can able to survive 47°C.

- **Distribution and status:** India, Algeria, Greece, United States, New South Wales (Australia), Japan, China.
- **Host range:** Paddy, rice, wheat, maize.
- **Damaging stage:** Both adults and larvae.

**Symptom of damage**

Both adults and grubs bore the grains and feed voraciously. Severe infestation leads to only leave with frays. Insects are not swift movers and can easily hide in the cracks and underneath damage flour.

**Detection:**

The insects can be either detected based on the random sampling and record for the holes in the grains or by adults moving on grain. Grubs and adults completely feed on internal material and leave the husks and flour with sweet smell/fungus smell at severity. The insect outside the grain can be detected by sieving which discharges the adults to fall down from the grain.

Morphologically adults are dark reddish brown in colour. Female insects lay eggs in single or in groups. Grubs are whitish and are funneling inside the grains.

**b. Pulse beetle: *Callosobruchus chinensis* (L.) (Coleoptera:Bruchidae)**

*Callosobruchus* spp. is important primary pests of pulses. Infestation may start in the pods before harvest and carry over into storage where substantial losses may occur. Levels of infestation may be high. The insects are able to cause damage in almost all types of stored pulses. They prefer whole grains for damage initiation/egg laying.

- **Distribution:** Cosmopolitan.
- **Host range:** All whole pulses, beans and grams.
Egg
- Egg period is 6 - 16 days
- Fresh eggs are translucent, orange cream in colour, changing to greyish white with age.

Adult
- The adult beetle measuring 3 - 4 mm in length
- The average lifespan of an adult is 5 - 20 days.

Larvae
- Larva is whitish with a light-brown head.
- The mature larva is 6 - 7 mm long.
- Larval period 10 - 38 days.

Pupae
- The pupal stage lasts 4 - 28 days.

Figure: Pulse beetle, *Callosobruchus chinensis* (L.) (Coleoptera:Bruchidae)

- **Damaging stage:** Both adults and larvae.

**Symptom of damage:**

Female insects lay eggs on the whole grains and this is the initial symptom or early detection method of insect. The grub after hatching enters into the seed and devours completely the internal material and leave the empty outer coat.
Detection:

*Callosobruchus* spp. Lays egg on the grain surface, this presence of eggs is the first line of detection. After feeding of the grain the exit holes caused by the adults was one more detection symptom. But by the time exit holes are visible, the insect completely infested the grain and of no use.

Pulse beetles are generally got the name because they mainly feed on all pulses. The insects are dynamic and fly quickly at exposure to light. Although seven species of *Callosobruchus* are common in India, *C. chinensis, C. maculates, C. analis* are severe. They are generally differentiated based on the colouring pattern of body. Adults are short lived and their main purpose is to find mate and lay eggs for the continuation of generation.
5. Grain and flour beetles

a) Saw toothed grain beetle: *Oryzaephilus surinamensis*, (Coleoptera: Bruchidae: Silvanidae)

Saw toothed grain beetle is one of the best known cosmopolitan species. It is a slender, flat brown beetle. The thorax part has six saw tooth like projections, hence the name given. These insects are

**Egg**
- Eggs are white in colour, laid loosely in cracks of storage receptacles and godowns.
- Hatching Period is 3-17 days.

**Adult**
- Adult insects are narrow, flattened having six teeth like serrations on each side.
- Female can lay upto 300 eggs.

**Larvae**
- Larvae are slender with two darker patches on each segment.
- Larval period is 14-20 days.

**Pupae**
- Full grown larvae form the cocoon like covering with sticky secretion and pupate inside.
- Pupal period is 7-21 days.

*Figure: Saw toothed grain beetle, Oryzaephilus surinamensis (Bruchidae:Silvanidae)*
recently placed in silvanidae, earlier are under cucujidae. These insects are typically secondary pests mainly feed on damaged grains primarily damaged by other insects or mechanical damage. Larva can attack the germ in whole cereal grains. They reduce the nutritional content of the grains and reduce germination. In addition, damage grains produce off odour upon severe infestation. Though the insects are winged but rarely fly. They always wandering in search of food and rest in crevices, ducts and roofing spaces, from they are difficult to eradicate.

- **Distribution and status**: Cosmopolitan and common in worldwide pest of grain and grain products as well as chocolate, drugs and tobacco.

- **Host range**: Feed on food of vegetable origin, grains and grain products

- **Damaging stage**: Both adults and grubs

**Detection:**

Adults can be seen upon careful observations, if the number is more. However, insects are able to climb on glass surface also; they can be seen on container walls. Using pitfall traps for detection of these insects is unsuitable idea. Since these are secondary pests, generally they found in the damaged grains.

b) **Rusty grain beetle: Cryptolestes ferrugineus (Stephens) (Coleoptera : Laemophloeidae)**

These insects are reddish brown in colour, most common instored cereal especially wheat. Adults and larvae feed mostly on the germ portion of grains. Severe infestation causes increase in grain temperature and contaminate the grains with faeces and also spread the fungal spores. Though the adults are winged but rarely fly. Adult insects walk with a characteristic swaying movement.

- **Distribution and status**: Worldwide distribution and is resistant to cold than other flat grain beetles.

- **Host range**: cereal grains, oilseed cakes, tobacco and dried store products

- **Damaging stage**: Both adults and grubs
Egg
- Each female can lay upto 200 to 500 eggs & Eggs are laid loosely on or among the grains.
- Hatching in 3 to 5 days under favourable temperature (30°C).

Adult
- Adult is a shiny reddish brown beetle about 2 mm long.
- It moves rapidly in warm grain and lies within the temperature above 25°C.

Larvae
- The larvae are worm like and are white in colour with two projections at tail end.
- Feeding on germ portion and pupate inside the grain.

Pupae
- Pupation is inside the grains after feeding the germ portion.
- The total lifecycle ranges from 35 to 150 days based on the climatic condition.

Figure: Rusty grain beetle: Cryptolestes ferrugineus (Stephens) (Coleoptera: Laemophloeidae)

Detection:
These are several closely related Cryptolestes spp. with similar appearance and habits. Larvae and adults characteristically feeding externally on damaged grains.
c) Rust-red flour beetle: *Tribolium castaneum* (Herbst) (Coleoptera : Tenebrionidae)

Red rust flour beetle and confused flour beetle are two almost similar insects generally confusing between. These beetles are generally encountered with stored food products irrespective of whether primary and processed ones. These are secondary invaders which are not able to cause primary damage and associated with the primary feeders. They multiply rapidly when the food source is

**Egg**
- White, translucent, sticky, slender and cylindrical.

**Adult**
- Oblong, flat, brown in colour.

**Larvae**
- The young larva is yellowish white and measures 1 mm in length.

**Pupae**
- The pupa is yellowish and hairy.
- The pupal stage lasts 5-9 days.

*Figure: Rust-red flour beetle: *Tribolium castaneum* (Herbst) (Coleoptera : Tenebrionidae)*
rich with protein material. They can easily establish in the households, granaries, shipment mills, warehouses etc.

- **Distribution and status:** Cosmopolitan, but more common in warmer regions. This pest occurs in temperate areas, where it survives winters in protected places, especially with central heating.

- **Host range:** Wheat-flour, dry fruits, pulses and prepared cereal foods, such as cornflakes.

- **Damaging stage:** Both adults and larvae.

**Symptom of damage:**

Adults and larvae feed mainly on the germ of the cereal.

**Detection:**

At lower densities, these insects are difficult to detect. However, in flour tunnels can be visible because of the adults and grubs movement. The flour kept for 15-20 days undisturbed generally infested by these beetles and bad odour is a symbol of severe damage. The grain/flour quality completely deteriorate, if the measures not taken up immediately. The adult are fast movers and good fliers and are easily visible, is the main sight of detection.

Adults are reddish brown i.e. rusty red and the body is flattened. During unavailability of food these insects overwinters in cracks and crevices of the warehouses/walls. The grubs and pupae are pale in colour. These insects can be easily separate from flour by sieving. They are the main host for many laboratory studies. In India, this insect is reported with phosphine resistance upto 35 folds.

d) **Flat grain beetle: Cryptolestes pusillus (Schönherr)(Coleoptera: Laemophloeidae)**

Flat grain beetle belongs to *Cryptolestes* genus are minute pests of stored grains. *Cryptolestes pusillus* and *C. minutes* are the two important species commonly found. Recently the group is included and pronounced as *Laemophloeus* belonging to *Laemophloeidae* family. These are smallest beetles, both adults and larave attack almost all types of grains and grain products including dried fruits, groundnut seeds and oilseed cakes. Rapid reproductions leads to increase in number and are generally found in association with many other stored insects like rice weevil, flour beetles etc.
**Egg**
- Female lays eggs in seed/grain cracks or even drop them loosely upon the farinaceous material.
- Eggs are white in colour and hatch within 5-6 days.

**Adult**
- Adults are reddish brown beetles smallest of all stored grain insects, approximately 1.5 to 2.0 mm.
- The total life cycle is 40-46 days.

**Larvae**
- Larvae are generally active in feeding and after hatching, they search the damaged grains. The larvae also feed on dead insects.
- Larvae are cigar like yellowish white having the larval period of 21 days.

**Pupae**
- Fully grown larvae form like gelatinous cocoons adhering to the food materials, pupation is inside these cocoons.

**Figure: Flat grain beetle: Cryptolestes pusillus (Schönherr) (Coleoptera: Laemophloeidae)**

- **Distribution and status:** Worldwide present. But *C. minutus* is common in low temperature regions. *C. pusillus* confined to southern hemisphere.

- **Host range:** Almost all grain and grain products including oilseed cakes, dried fruits etc.

- **Damaging stage:** Both adults and grub. They are secondary pests and are unable to survive in sound uninjured grains.
Detection:

Since the grubs are very minute, are unable to detect with naked eyes if less in number. However, an adult are free moving in the grain and are rapidly multiplying, leads to trap easily with any probe traps.

e) Confused flour beetle: *Tribolium confusum* (Coleoptera: Tenebrionidae)

- **Distribution and status:** The confused flour beetle, originally of African origin, has a different distribution in that it occurs worldwide in cooler climates.

  - **Egg**
    - Females lay an average of about 450 eggs, which are small and clear white.

  - **Adult**
    - \(\frac{1}{8}\) to \(\frac{1}{4}\) inch in length, and reddish-brown in colour.
    - The average life of adults is about one year.

  - **Larvae**
    - Larvae (small brownish-white worms) hatch in five to twelve days.
    - Full-grown in 30 to 40 days.

  - **Pupae**
    - Pupal period is 5-8 days.

*Figure: Confused flour beetle:* *Tribolium confusum* (Coleoptera: Tenebrionidae)*
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- **Host range:** flour, cereals, meal, crackers, beans, spices, pasta, cake mix, dried pet food, dried flowers, chocolate, nuts, seeds.

- **Damaging stage:** Both adults and larvae.

**Symptom of damage:**

Adults and larvae feed mainly on the germ of the cereal.

**Detection:**

These insects are similar to rust-red flour beetle and are confusing. These insects are comparatively established well in lower temperatures than preferred by rust red flour beetle. The life cycle is almost similar for both of the species. Insects are generally prolonged with life cycle in winter and generally finishes total life cycle in 6 weeks under favorable conditions.
6. Dermestid beetle

a) Khapra beetle: *Trogoderma granarium* Everts (Coleoptera:Dermestidae)

These insects are having great quarantine importance worldwide and present in India in many European countries. These insects are having zero tolerance pests. Insect can be able to attack any dried plant or animal matter but it prefers mainly grain and cereal products. In Indian conditions,

**Egg**
- Female laid 13-35 eggs, either in single or in cluster.
- Egg laying was there upto 1-7 days.

**Adult**
- Adult are reddish brown, convex, oval in shape practically no distinct division of head, thorax and abdomen.
- They are incapable of flying.

**Larvae**
- The larvae is straw coloured having the dark brown hair band.
- Larval period is approximately 20-40 days.

**Pupae**
- Pupation takes place in last larval skin among the grains or on the surface and overlapping with the storage bags.
- Pupal period is 4-6 days.

*Figure: Khapra beetle, *Trogoderma granarium* Everts (Coleoptera:Dermestidae)*
khapra beetle is mainly suffering its severity in wheat storage but can actually able to infect other commodities/grains also. Generally these insects breed from April to October in the active day. During warmer months i.e. July to October, the infestation is severe.

- **Distribution and status:** Tropical and subtropical countries mainly found in hot and dry region. It prefers lower humidity and higher temperature.

- **Host range:** paddy, jowar, wheat, maize, oilseeds and pulses. Even wide range of stored products, packaged goods and handling facilities can also be affected.

- **Damaging stage:** Grubs are the voracious feeders. Adults are mainly involved in breeding.

**Detection:**

Grubs are the damaging stage and feed on the germ portion by scratching even they finish entire grain. The exuviate was contaminating the grain maximum, with slight winnowing in handful of grains can give an idea about grub’s presence. Except wheat, in other commodities grubs and adults can be easily differentiated. Since the grubs are positively thigmotactic, they can be collected by merely placing gunny bags on a heap of grains. Adults can be seen on the surface of grains while moving.
7. Miscellaneous beetles

a) Cigarette beetle: *Lasioderma serricorne* (Coleoptera:Anobiidae)

Cigarette beetles are frequently found in warmer regions but having their distribution in warmer to colder regions but they are mainly in warmer regions. Though they are named as cigarette, they

**Egg**
- Female lays creamy white eggs on the surface of the stored material.
- The eggs hatch in 9-14 days.
- A single female can lay about 110 eggs.
- Eggs are laid in folds and crevices of food material.

**Adult**
- Adult are light brown and round beetle with thorax and head bent downwards, looking like a hump.

**Larvae**
- Newly hatched larvae are less than 1 mm in length and covered with fine hairs.
- Head of larvae is yellowish and has a semi-transparent and white body.
- Larvae damage the grains by making galleries.
- Larval period is approximately 25-30 days.

**Pupae**
- The fully grown larvae transformed into pupa within a cell/cocoon made of chewed food material, newly formed pupa is glossy white.
- Pupal period is 4-6 days.

Figure: Cigarette beetle, *Lasioderma serricorne* (Anobiidae: Coleoptera)
are not infested on stored tobacco leaves but also the large number of the other dry vegetable products, oilseeds, oilseed cakes, dried fruits etc. but practically all damage is done by larvae. Insect is active throughout the year in warm buildings, in temperate and subtropical regions and development slows down during winter as other insects.

- **Distribution and status:** Cosmopolitan but prefers warm environment

- **Host range:** A wide range of commodities, but prefers to feed on cigarettes, chesools and chewing tobacco, chocolate, spices

- **Damaging stage:** Both grubs and adults

**Detection:**

Presence of circular pinhead sized holes on processed tobacco in the typical symptom of attack. The grubs are tunneling inside the cigarettes and after transforming to adults they exit leaving hole on commodities.

**b) Drug store beetle: Stegobium paniceum (Linnaeus) (Coleoptera: Anobiidae)**

Drugstore beetle, as name indicates they are mainly pest of stored spices. They have a tendency towards to feed on pharmacological/medicinal products as per ancient druggists but are feed on stored fruits, oilseeds, dried vegetables and plant products. These are primary pests of turmeric, ginger, pepper, coriander seeds etc.

- **Distribution and status:** Virtually cosmopolitan, more temperate than tropical

- **Host range:** A wide range of commodities, but prefers to feed on cigarettes, chesools and chewing tobacco, chocolate, spices

- **Damaging stage:** Both grubs and adults

**Detection:**

Infestation of drugstore beetles is similar to that of cigarette beetles. The exit hole of adult beetles appeared as shot like holes in infested products. These are also associated as an obligali symbiotic
**Egg**
- Adult female can lay up to 20 to 100 eggs. The eggs are laid on food material and are sometimes covered with yeast.
- Egg period is 8-10 days.

**Adult**
- Adults are small reddish brown beetles having wing. These are slightly larger than cigarette beetles. Adults are short lived.
- During afternoon to evening, these are active fliers. Adult female during favourable conditions can live up to 65 days.

**Pupae**
- Pupation is inside the damaged food products or in damaged products.
- The grub forms the cocoon and pupates inside.
- Pupal period is 4-6 days.

**Larvae**
- The hatched out grubs are similar to cigarette beetles.
- The larva damages the commodity nearly by tunneling.
- The larval period ranges from 4-20 weeks.
- In a warmer condition, they complete four generations per year.

**Figure: Drug store beetle, Stegobium paniceum (Linnaeus) (Coleoptera: Anobiidae)**

with fungus and are transferring from generations. The adults are active and can be seen flying or moving in the commodities. While, the grubs are feeding internally by making galleries.
c) **Groundnut bruchid: Caryedon serratus (Coleoptera: Chrysomelidae)**

Bruchids are known to infest mainly groundnut commonly but are also reported on tamarind and four species of Fabaceae. These are prevalent in India under Gujarat, Karnataka, Andhra Pradesh,

**Egg**
- Small translucent milky white eggs laid on pods. Female can lay upto 60-70 eggs and the incubation period of eggs is 4 days.
- Irrespective of the egg density, only 2 adults emerge out of one-sided pod/kernel and 4 to 5 adults from 2-3 seeded pods.

**Adult**
- Adults are dark brown in color having sexual dimorphism.
- The posterior part of abdomen (Pygidium) is explored in female.
- Adult longevity is 15-20 days. Females are short lived than males.

**Larvae**
- Larvae upon hatching started scraping pod/kernel surface and penetrate into pod to feed on kernels.
- The larvae having four instars and larval period are approximately 50 days.

**Pupae**
- The fully grown grub emerges out by making an exit hole and constructs a tough silken cocoon on the surface of pods/kernels.
- Grubs pupate inside silken cocoon, having pupal period of 12 days.

*Figure: Groundnut bruchid: Caryedon serratus (Coleoptera: Chrysomelidae)*
Maharashtra and Tamil Nadu. Generally, infestation starts from field where the adults laying eggs on the pods and was carried to storage.

- **Distribution and status:** These are common in almost all groundnut growing countries. In India, it is most severe in Gujarat. Even its artificially tropicopolitan because of its association with *Tamarindus indica*.

- **Host range:** Groundnut, apart from it, also attacks four genera of Fabaceae. Tamarind is considered as most suitable host.

- **Damaging stage:** Mainly grubs

**Detection:**

First sign of attack is appearance of windows cut into pod wall by larvae. The larvae burrows through pod wall and eat seeds. They damage both qualitatively and quantitatively. Increase in temperature because of higher metabolism rate. Indirectly also contaminate by aflatoxin spreading.
8. Grain moths

a) Angoumois grain moth: *Sitotroga cerealella* (Olivier) (Lepidoptera:Gelechiidae)

The insect names come after its first notice during 1736 from Angoumois province of France. It is one of the most internal feeding destructor. Infestation starts from field itself during ripening/

**Egg**
- The female lays up to 150 eggs on the outside of kernels and in cracks.
- Egg period is 4-8 days.

**Adult**
- The adult is a buff, grey yellow, brown or straw coloured moth, measuring about 10-12 mm in wing expanse.
- Adult live for about 4 - 10 days.

**Larvae**
- A full grown larva is about 5 mm long, with a white body and yellow brown head.
- Larvae capable of tunnelling sound grains.

**Pupae**
- Larvae spins a silken cocoon inside the grain and changes into reddish brown pupa. Before pupation, larvae cut a circular opening on husk which is covered by silken cover to come out.
- Pupal period is 9 - 12 days.

Figure: Angoumois grain moth: *Sitotroga cerealella* (Olivier) (Lepidoptera:Gelechiidae) [Ref. Chitrasrivastava, TNAU, USDA]
milking stage. However, in storage infestation restricts to surface. Infestation produce abundant heat and moisture that may encourage mold growth and attract secondary pests.

- **Distribution and status:** Cosmopolitan, more abundant in warmer regions. However, in Indian conditions, pest is abundant in milder conditions.

- **Host range:** Regarded as most destructive internal feeder mainly attacking paddy, maize, sorghum etc. before harvest also.

- **Damaging stage:** Larvae, only whole cereals are attacked, greatest damage occurs in the upper layer grains in storage

**Detection:**

Early infestation is difficult to detect because hole made by young insect is so small that it cannot be seen. Larva enters and its way in the grain, the turns about and spins a silken wets over the opening by which it entered that it is difficult to locate it. The appearance of moths in the stores and round holes in grains/heating of grains is first indication.

**b) Rice moth: Corcyra cephalonica (Stainton) (Lepidoptera: Pyralidae)**

Rice moth is one of the key pests of rice, cocoa, confectionary, cereal grains etc. Adult insects do not feed and live for only 1 or 2 weeks. These are external feeders, which feed on grains by webbing them together. Rice moth is widely used for rearing of natural enemies in the laboratory use in field against crop pests as it is easier and cheaper to produce natural enemies on different stages of *Corcyra trichogramma* spp. is used for mass-breeding.

- **Distribution and status:** The rice moth is distributed in Asia, Africa, North America and Europe. In the larval stage, it is an important stored-grain pest in both India and Pakistan. Distributed well in all rice growing areas.

- **Host range:** Paddy, rice, wheat, maize, sorghum, millet, dried stored product.

- **Damaging stage:** Larva
**Egg**
- Eggs are whitish, oval in shape, 0.5 mm long and having an incubation period of 4-5 days.

**Adult**
- Adults light greyish-brown in colour, 12 mm long.
- Wing span of about 15 mm.

**Larvae**
- Full grown larva is pale whitish in colour
- 15 mm long with short scattered hairs and no markings on body.

**Pupae**
- Pupal period is about 10 days but may extend to 40-50 days to tide over winter.

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**Figure: Rice moth: Corcyra cephalonica (Stainton) (Lepidoptera: Pyralidae)**

**Detection:**

Larvae cause the damage by webbing together grains and forming lump and feed from inside it. Larvae leave a lot of webbing in the grains before pupation, causing excessive lumping, which reduces marketing quality of the grains. C. cephalonica adults can be seen resting on store surfaces and have a peak of flight activity at dusk. The larvae crawl over the stored food and in the last instar construct cocoons that may be found within the stored food, on sack surfaces and store structures. Infestations cause a bad smell.
9. Indian meal moth: *Plodia interpunctella* (Hubner) (Lepidoptera: Pyralidae)

Indian meal moth commonly called as weevil moth, pantry moth or flour moth. It is generally confused with almond moth (*Candracantella*). The larvae are commonly known as waxworms.

**Egg**
- Eggs are laid singly or in clusters and stick to various foods by a sticky secretion.
- Eggs hatch in 4-20 days.

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**Adult**
- Adults mate immediately after emergence and start the life cycle.
- Female moth can lay 30-350 eggs in a minute. Adults generally do not feed.

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**Pupae**
- The fully grown larvae make threaded cocoons and pupate inside. Sometimes pupa is often seen on grain surface and on wall of bins.
- Pupal period is 4-10 days

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**Larvae**
- Larvae having 5-7 instars. Newly hatched larvae feed on grain while mature larvae feed on grain germ.
- White colour larvae having polychromy in pink, brown and greenish.
- Fully grown larvae able to spin webs and leave silk threads in their path of travel.

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*Figure: Indian meal moth, Plodia interpunctella (Hubner) (Lepidoptera: Pyralidae)*
These are common storage pests around the world infecting stored cereals, fruits and similar products. Larvae are able to bite through plastic and cardboard also. The moths are generally active from dusk until dawn, rests during day. The adults are easily distinguished from other grain pests with peculiar markings of the forewings which are reddish brown with a copper luster on body ends.

- **Distribution and status:** A native to America, but now a cosmopolitan species. Adapted to wide range of climates around the world.

- **Host range:** Wider host range includes stored grains and pulses, dried fruits and nuts, dried vegetables and processed foods.

- **Damaging stage:** Larva

**Detection:**

Larvae creates more severe problem by feeding and contaminating produce through faeces. Larvae feed by webbing. The webbing may also cause condensation which leads to damaging molds. Crawling caterpillars completely web over the surface of heap of grains with silken threads. The adults fly from one bin to another and spread the infestation.
General management of stored product insects

Although, insect management options like physical, mechanical, biological and chemical practices are available, in India fumigation was practiced since long time in storage. Some of the general preventive and curative management options are listed below.

I. Preventive measures

- Drying of the grains to a moisture range of 10 to 14% based on grain type, avoid majority of the damage. Drying can be done under sunlight or using any developed dryers.

- After harvesting of the grains before shifting to storage, certain measures have to take the initial infestation or inoculum of storages pests. Some of the preventive measures are listed below,

- Sanitation of storage site is prerequisite, which involves removing of dirt, debris, foreign particles, other insects and infested grains that will reduce avoid initial infestation.

- Handling of grains should be proper and the storage structure should not be damaged. Proper stacking size and wooden dunnage should be maintained to avoid from mechanical damage or to keep away from wall. Between each stacks a proper space should be maintained.

- Sometimes the initial infestation observed in field can be managed with exposing the grains for sunlight for shorter period.

- Using of improved storage structures. In Indian conditions grains are storing variedly from small metal bin to bulk storage in gunny bags under warehouses. Hermetic storage concept developing can be exploited for the future. Jute bags are generally using, which are additionally suggesting to amalgamate with polythene lining.

- Newer lots have to store separately and should have isolated distance between old stocks.

- Several improved bins are available, which are developed by different institutes for Indian conditions like, Pusa bin, PAU bin, TNAU bin, etc. can be used.

- Disinfestation of bulk and bag storage structures using insecticides is also an important practice to be done prior to storage and a layer of insecticide spray can be suggested
immediately after storage. Since, dichlorvos was banned using in warehouses, presently deltamethrin and malathion are the available options for disinfectant and for surface sprays.

II. Curative measures

a. Physical methods

1. Temperature management: Increasing or decreasing the temperature can alter the insect growth and metabolism. Optimal temperature for most of the storage insects is between 25 and 33°C. deviations from these points will slower down the growth and continuously to death. Passing of dry or wet heat in the storage system or refrigerated aeration yield better results. Even it can be achieved using high frequency waves.

2. Mixing of inert dusts: Inert dusts like clays, sand, ash, minerals, silica (silicon dioxide) are effective in managing the insects by moisture loss of the insect body by abrasion. Dusts that contain natural silica, such as diatomaceous earth (DE), are commercially available and using in many developing countries either to manage or to improve fumigation efficiency. Activated clay (kaolin) has also been used in protecting grains from the attack of storage insects.

3. Irradiation: Radiations in lower dose can able to kill or sterilizes the common grain pests, and even the eggs deposited inside the grains. Radiations like microwaves, x-rays, etc. are utilizing in several forms to treat the grains before storage to disinfest them.

4. Use of controlled atmosphere: A novel methodology where the storage atmosphere generally contains 78% Nitrogen (N2), 21% Oxygen (O2) and 0.03% carbon dioxide (CO2). This proportion can be altered mechanically by altered atmosphere which interfere with the normal insect metabolism which achieve mortality.

5. Mechanical devices, traps, etc.: Devices developed for monitoring and mass trapping such as entoleters, which are using in flour mills. TNAU under AICRP on Post-Harvest Engineering & Technology has developed different types of insects traps (TNAU stored insect kit). Apart from these some other traps like Probe trap, Pulse Beetle Trap, Light traps, Sticky traps, Bait traps and Pheromone were also developed and tested in some of the countries.
b. Biological control:

1. **Semiochemicals:** Much of the behavior of insect pests of stored products is associated with the search for food, sexual partners and egg-laying sites, together with defensive activities to protect them from adverse environmental conditions and natural enemies. This behavior is modified by chemical signals produced either by the insects themselves or by other organisms including the plants upon which they feed. This includes pheromones and allelochemicals. Insect traps are available for some of the insects like flour beetles and lepidopteran insects.

2. **Botanicals:** Plant extracts or products having insecticidal properties like Neem leaf powder, black pepper, turmeric powder, Sweet Flag Rhizome powder etc were also proved their effectiveness in amanging the stored grain pests. General dosage is 10g / kg of grains should be mixed. Different formulations like tablets, pellets, oils, etc are developing and are required commercialisation.

3. **Biopesticides:** Some of the commercially available entomopathogenic fungi against field crop pests like *Beauveria bassiana*, *Metarhizium anisopliae* and bacterium - *Bacillus thuringiensis* (Bt) were tested majorly against stored-grain pests especially beetles.

c. Chemical management:

In India, fumigation using phosphine is the only available option as methyle bromide was phased out. Aluminium phosphide (Alphos, Celphos, Phosphume, Quickphos, etc.) recommended for cover fumigation @ 3 tablets of 3 g each per tonne of grain, for shed fumigation @ 21 tablets of 3 g each for 28 cubic metres. 5 to 7 days, the fumigation should be done and made leakage proof. Sand snakes are used in case of cover fumigation. Nowadays, precipitate silica is also used against stored pests.
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Websources:

TNAU, India - http://agritech.tnau.ac.in/crop_protection/crop_prot_crop_insect_grain_pest.html

